
NGC 2207 / IC 2163

Space Interferometer Mission (SIM)

Presented by

Tom Fraschetti

Project Manager

SIM Key Objectives

*Science **

Indirect Planet Detection Down to a Few Earth Masses (goal: 1 μas; min: 3 μas)

Ultra Precision Global Astrometry (goal: 4 μas; min: better than 30μas)

** Technology maturation over the next few years will determine the ultimate achievable performance**

Technology

Demonstrate Technology of Synthesis Imaging

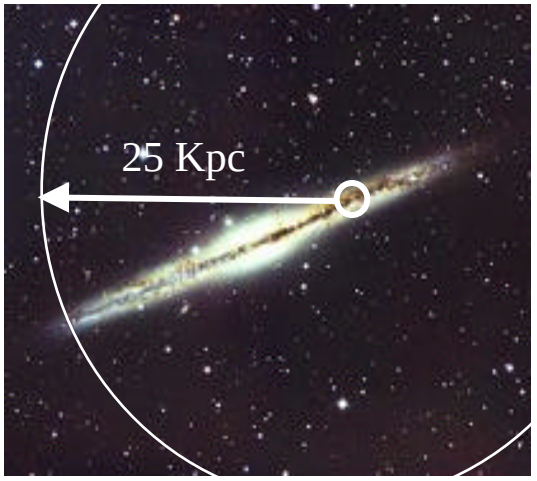
Demonstrate Technology of Starlight Nulling

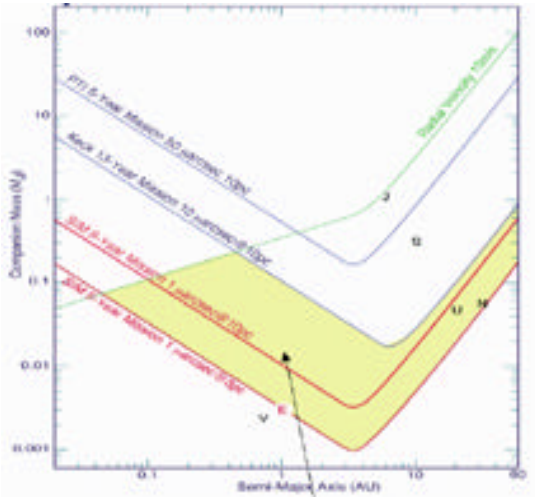
Usher in the Era of Long Baseline, Short Wavelength Interferometry for Astrophysical Observation

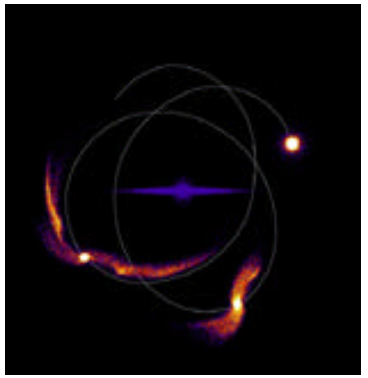
Astrophysics with SIM

New Discoveries …
and Answers to Age-Old Questions

- Calibration of the Cosmic Distance Scale
  - Cepheids and nearby spiral galaxies
- Dynamics of the galaxy
- Fundamental stellar astrophysics
- Star/Planetary system formation
  - The quest for terrestrial planets
- Masses of black hole and neutron star binaries
- Probe nature of dark matter via gravitational lensing
- Dynamics of the local group of galaxies, dark matter in nearby galaxies, and between galaxies
- Frame tie between SIM (optical) and ICRF (radio)







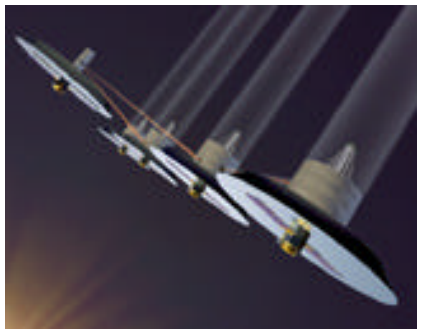
Space Interferometry Mission

SIM

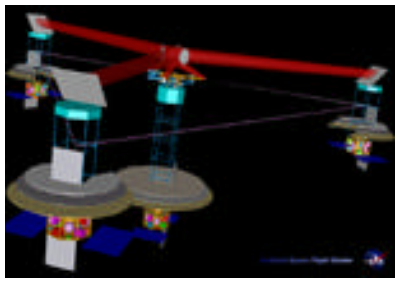
A NASA Origins Mission

SIM as a Technology Precursor to Future Missions

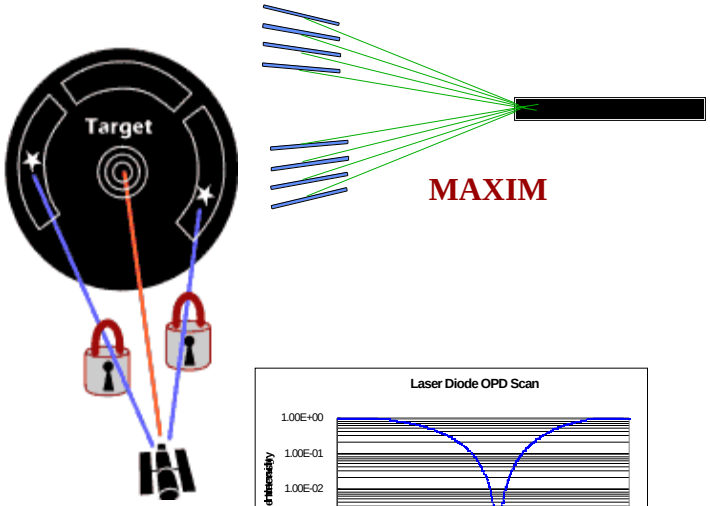
- SIM is an integral part of the flow of technology within the Origins Program and the Space Science Enterprise
  - TPF and future Planet Imaging Interferometers
  - Long baseline Interferometers from submm to X-rays
- SIM is a ***unique*** precursor for TPF in the following areas:
  - Angle and path length feed forward in space
  - Space demonstration of nulling to 10^{-4} (vis)
  - Imaging with a nulling interferometer (rotate a baseline while maintaining a deep null, moving delay line)



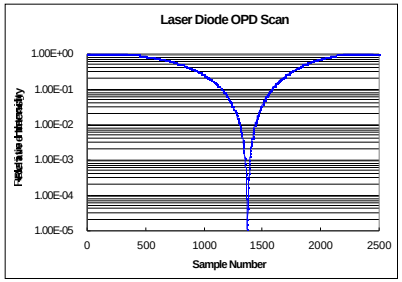
TPF



SPECS



MAXIM



Optical Nulling

Space Interferometry Mission

SIM

A NASA Origins Mission

Space Interferometry Mission

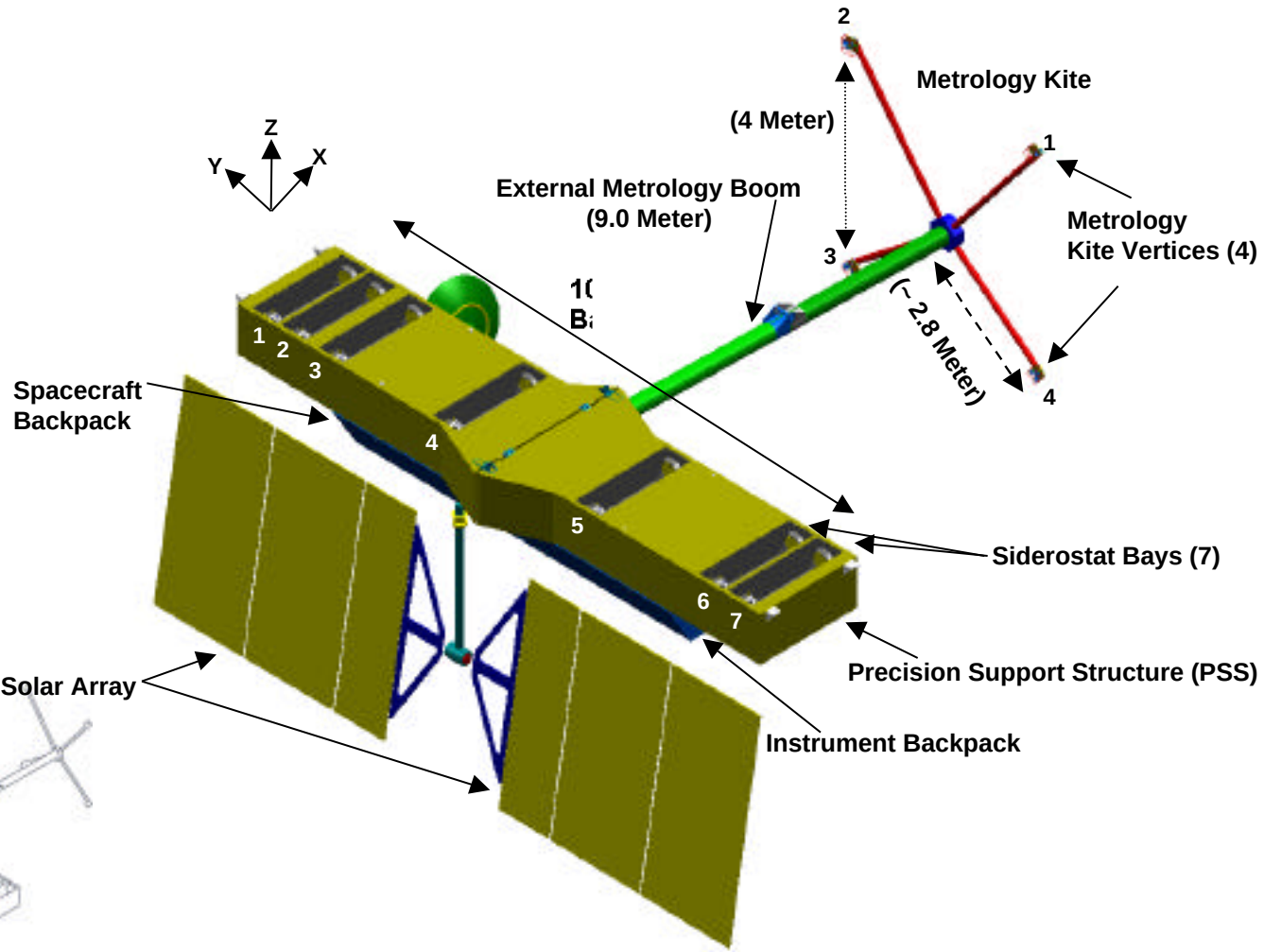
- 3 collinear Michelson Stellar Interferometers
- 10 meter baseline
- Visible wavelength
- EELV (Atlas V 421) launch vehicle
- Earth-trailing solar orbit
- 5-year mission life
- SIM is a JPL, Caltech, Lockheed Martin, and TRW partnership

Space Interferometry Mission

SIM

A NASA Origins Mission

SIM Flight System Configuration



Space Interferometry Mission

SIM

A NASA Origins Mission

The SIM Partnership: Four Partners

One Team

Metrology Subsystem
Starlight Subsystem
Interferometer I&T
Interferometer Operations

Spacecraft
Precision Structure
Assembly, Test, & Launch Operations
S/C Operations

Interferometry Science Center
Science Data Analysis and Archiving
Science Operations
Science Planning
Science Community Interface
Outreach

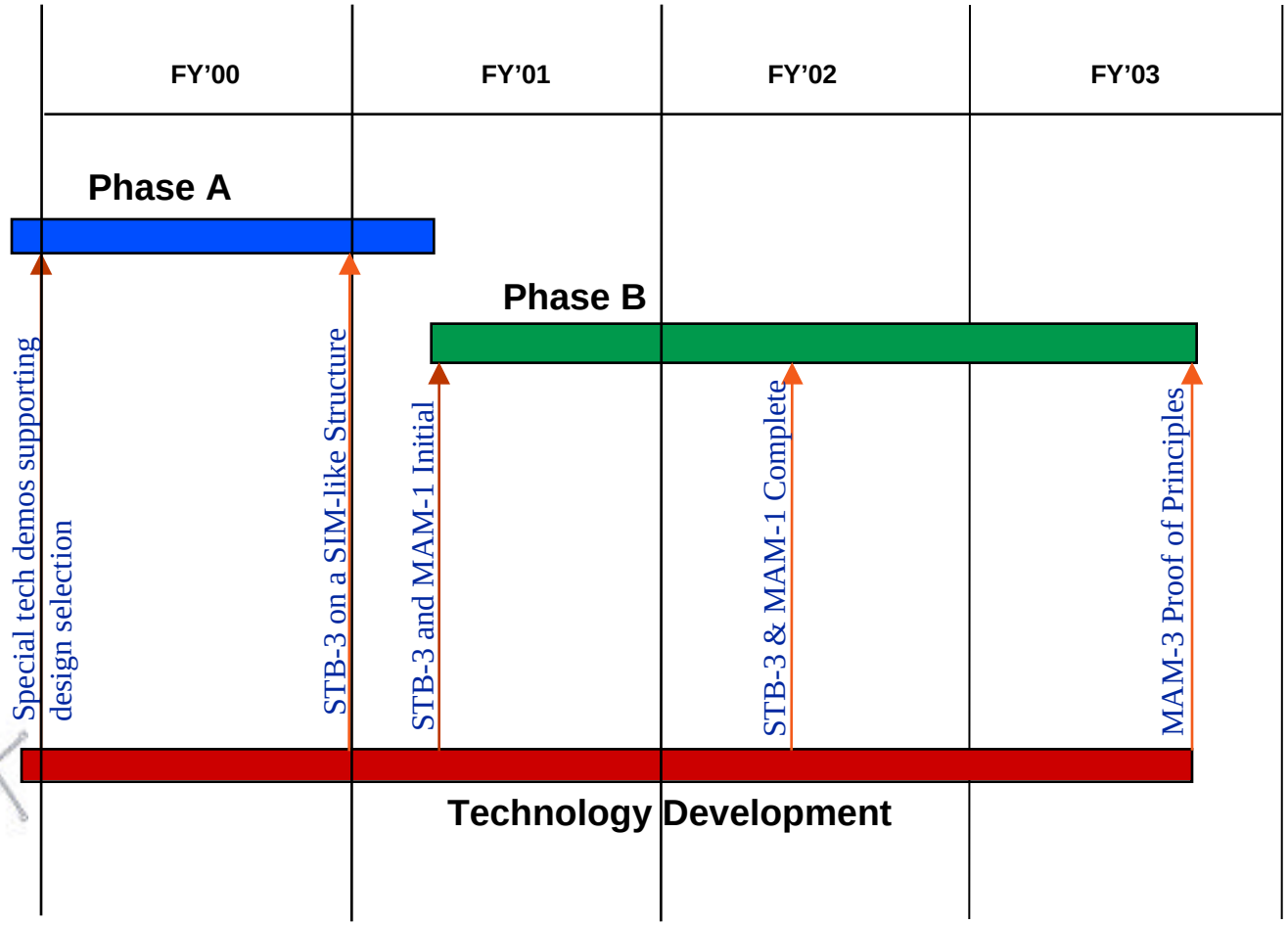
Project Management
System Engineering
Integrated Modeling
Real Time Control
Mission Systems
Mission Assurance
Risk Management

Space Interferometry Mission

SIM

A NASA Origins Mission

Near-Term Technology Schedule
Formulation Phase



Space Interferometry Mission

SIM

A NASA Origins Mission

Required Technologies

- Knowledge of positions of optical elements to 25 Picometers (*100 pm = diameter of a hydrogen atom*)
  - Picometer laser metrology
  - Picometer starlight fringe position measurement
- Nanometer control of optical path difference (*75,000 nm = thickness of a human hair*)
  - Nano-g vibration isolation
  - Nanometer/nanoradian active optics
  - Micron stability of structures
- Picometer thermal deformation of optics
  - Millikelvin thermal control of optics
- 10,000:1 starlight nulling beam combination in the visible

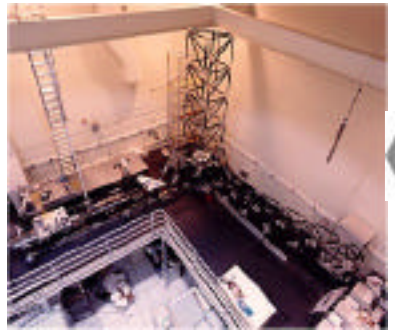
Space Interferometry Mission

SIM

A NASA Origins Mission

Approach to Technology Development

- Prototyping of technology component hardware and software
- Extensive use of ground testbeds to verify that the components play together at the system level
- Modeling, anchored by testbeds, predicts SIM end-to-end performance

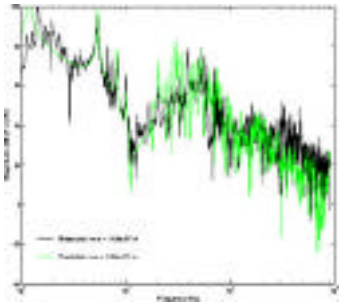


Testbed

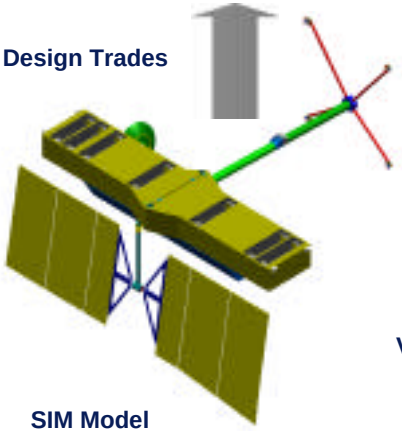
Component

Flight Ready Components

Design Trades



Testbed Model



SIM Model

Validated SIM Performance Predicts

Space Interferometry Mission

SIM

A NASA Origins Mission

SIM System Level Testbeds

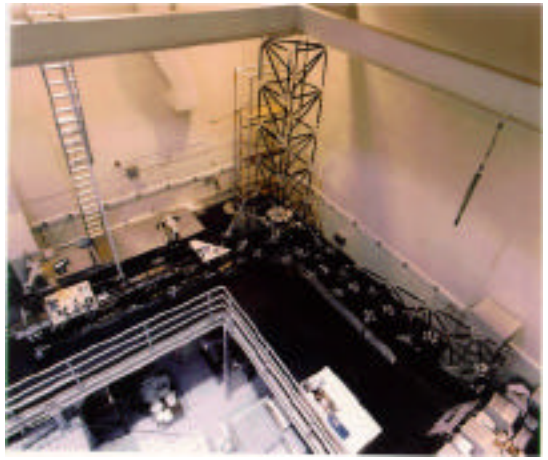
- SIM is developing four system level testbeds to demonstrate technology performance at the system level

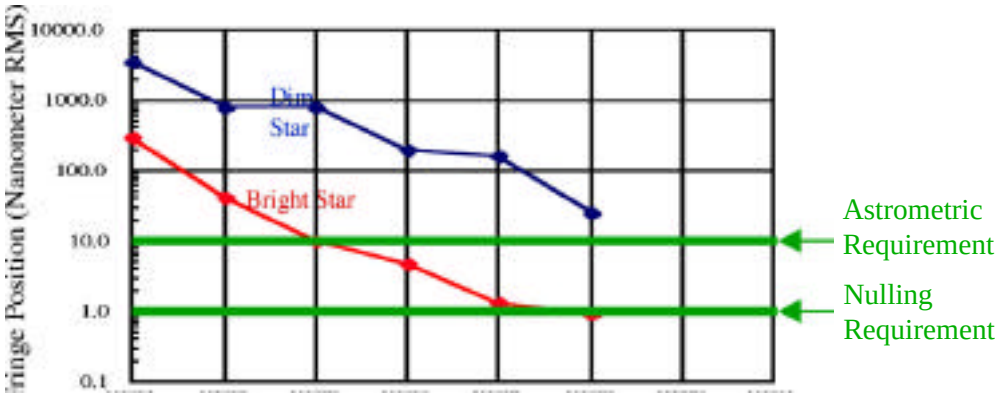
- Two near full-scale testbeds that demonstrate nanometer control in air
  - System TestBed - 1 (STB-1) is a one-baseline testbed
  - System TestBed - 3 (STB-3) is a three-baseline testbed

- Two sub-scale testbeds that demonstrate picometer knowledge in vacuum
  - MAM-1 is a 1/5 scale one-baseline testbed
  - MAM-3 is a 1/3 scale three baseline testbed

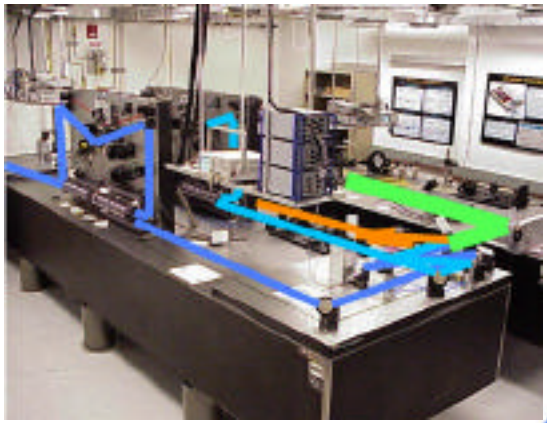
SIM System Testbeds (STB-1 & STB-3)

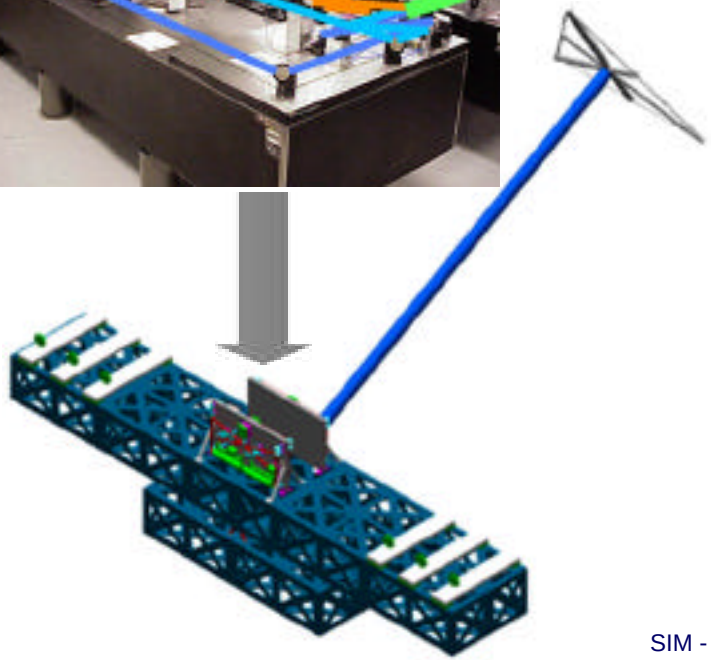
- STB-1 has been in operation since 1994
- Demonstrating nanometer stabilization for a single interferometer on a flexable structure
- Validating SIM dynamic modeling accuracy





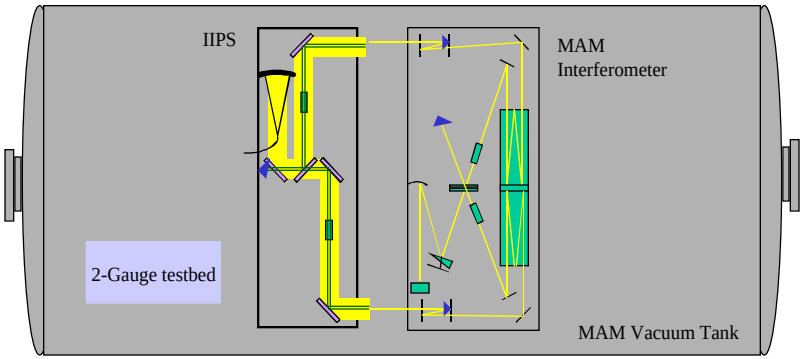
- STB-3 is presently operating on optical tables
- Will demonstrate pathlength feed forward, dim star control capability
- Will transition to a flexable structure in December 2000





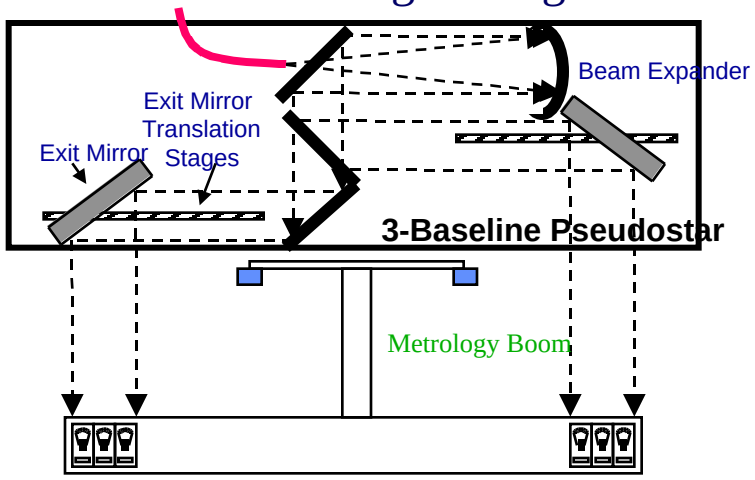
Micro-Arcsecond Metrology Testbeds (MAM-1 & MAM-3)

- MAM-1 is a 1/5 scale, one interferometer testbed
- Will demonstrate that metrology and starlight sensing can be integrated and provide consistent outputs at the picometer level
- Development of the interferometer and pseudo-star are in process
- Functional testing will take place in 2001



MAM-1 schematic

- MAM-3 is a 1/3 scale, three interferometer testbed
- Will demonstrate the transfer of guide star position knowledge with the precision required to measure science star positions in inertial space
- Requirements definition and conceptual design in process
- Will complete in time to influence the flight design



MAM-3 schematic

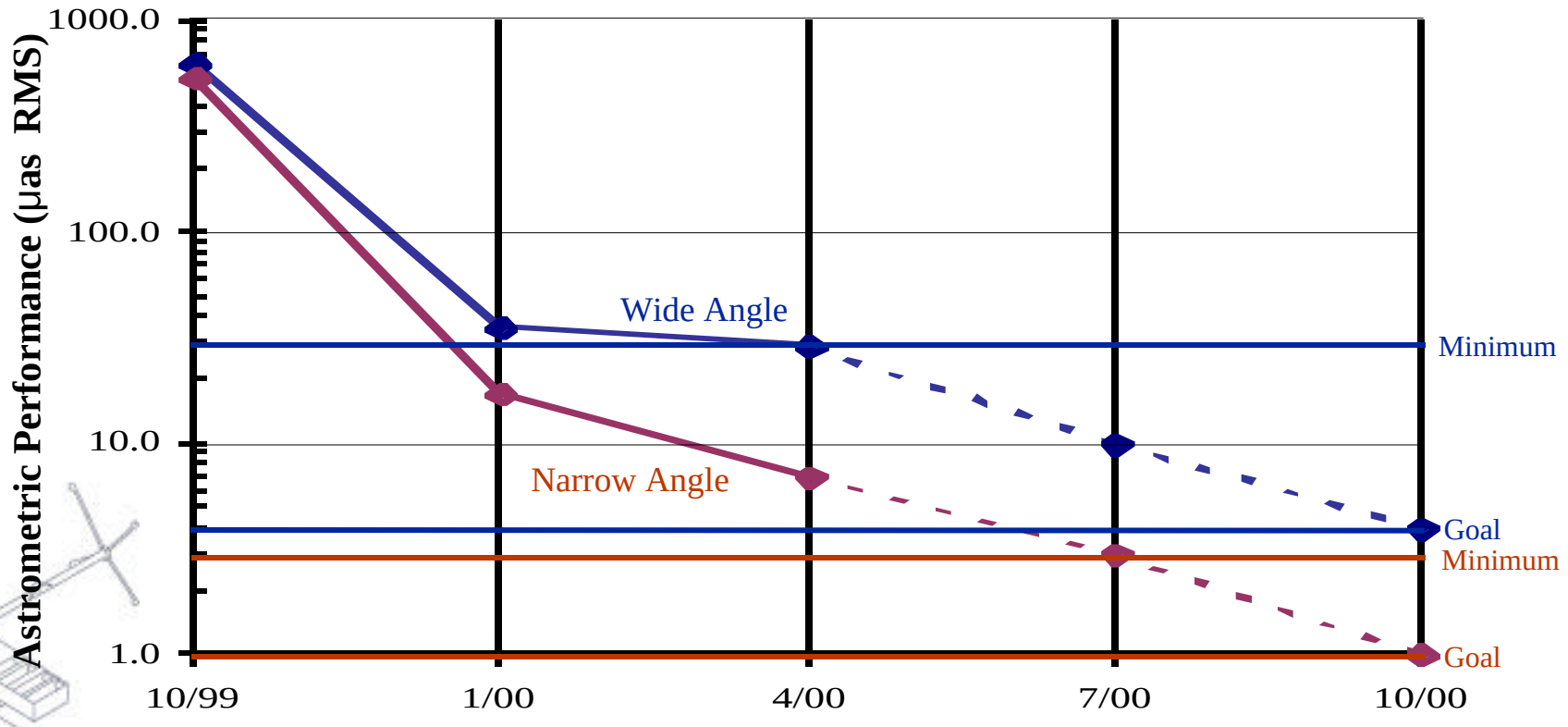
SIM Performance Metric

What If We Froze the Technology Now

	Parameters	Parameter Performance Today	Parameter Performance Needed by NAR	SIM Wide angle (WA) / Narrow Angle (NA) *What if all other parameters improve to the NAR level but no more improvement on this one*
1	Beam launcher thermal sensitivity (bulk, gradient)	**100 pm/mk, 2500 pm/mk**	**2 pm/mk, 50 pm/mk**	**28 µas/ 4.8 µas** ●
2	Cyclic averaging residual error per gauge	**100 pm**	**5 pm**	**4 µas/ 3 µas** ●
3	Pointing deter error per gauge	**750 mas**	**75 mas**	**5 µas/ 2.8µas**
4	Corner cube surface quality	**lamda/100**	**lamda/500**	**5 µas/ 1.2µas**
5	Wide angle error due to beam diffraction	**1000 pm**	**100 pm**	**8.5 µas (WA)**
6	Narrow angle error due to beam diffraction	**67 pm**	**2.7 pm**	**1.7 µas (NA)**
7	Wide angle error due to polarization effects on corner cubes	**375 pm**	**15 pm**	**10 µas (WA)**
8	Narrow angle error due to polarization effects on corner cubes	**25 pm**	**1 pm**	**2 µas (NA)**
9	1-D absolute metrology accuracy	**30 µm**	**3 µm**	**4 µas/1.2µas**
10	Wide angle PSS end-to-end thermal deformation	**100 µm**	**10 µm**	**4.4 µas (WA)**
11	Narrow angle PSS end-to-end thermal deformation	**10 µm**	**1 µm**	**0.9 µas (NA)**
12	Systematic fringe measurement error	**250 pm**	**30 pm**	**5.1 µas/3 µas** ●
	Wide Angle Performance (General Astrophysics) 4 µas (goal); 30 µas (min)	**29 µas**	**3.9 µas**	
	Narrow Angle Performance (Planet Detection) 1 µas (goal); 3 µas (min)	**7 µas**	**0.8 µas**	

SIM Performance Metric

- Calculated Wide Angle based on Component Performance
- Calculated Narrow Angle based on Component Performance



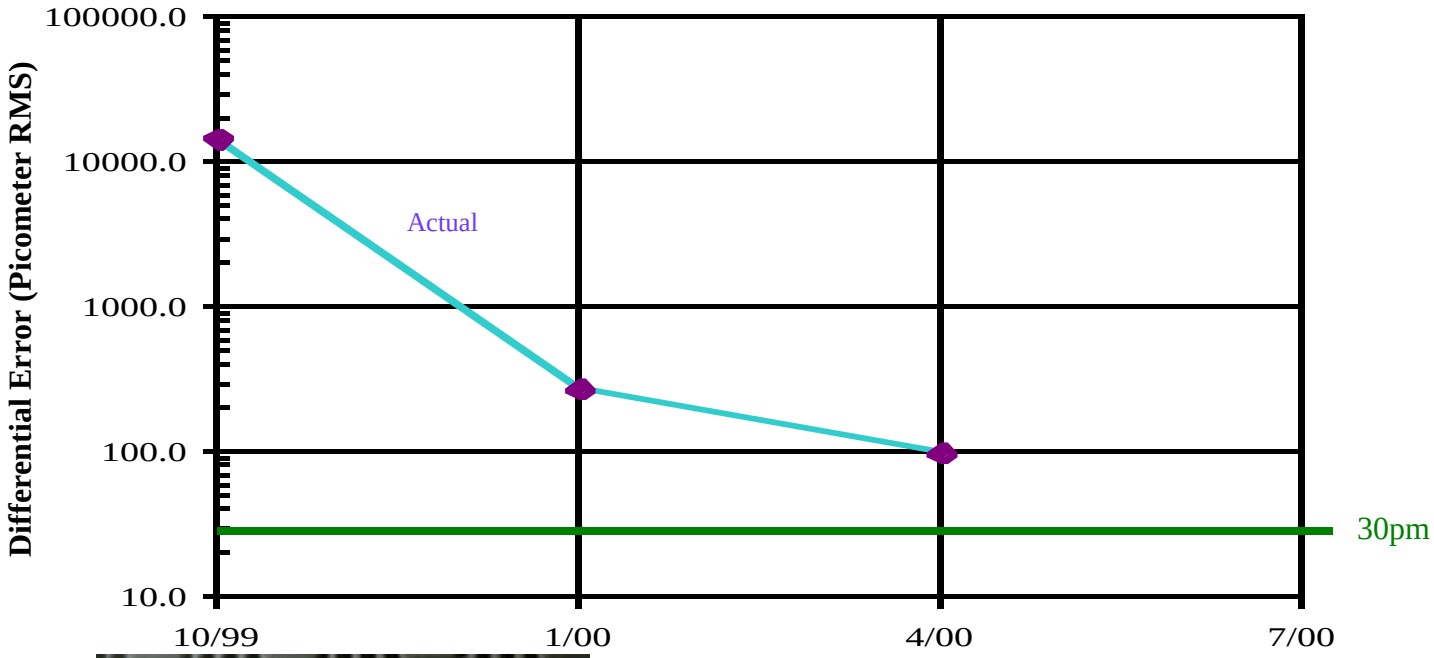
Space Interferometry Mission

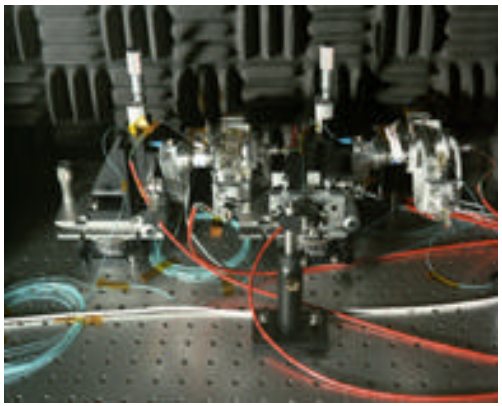
SIM

A NASA Origins Mission

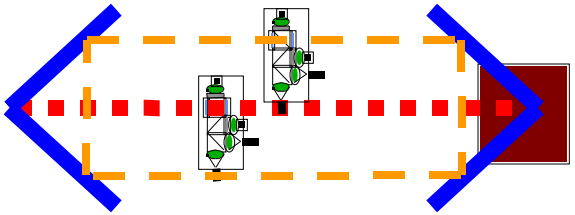
Metrology Gauge Experiment – Progress

- Measure agreement between two back-to-back gauges





Heterodyne Metrology Gauge



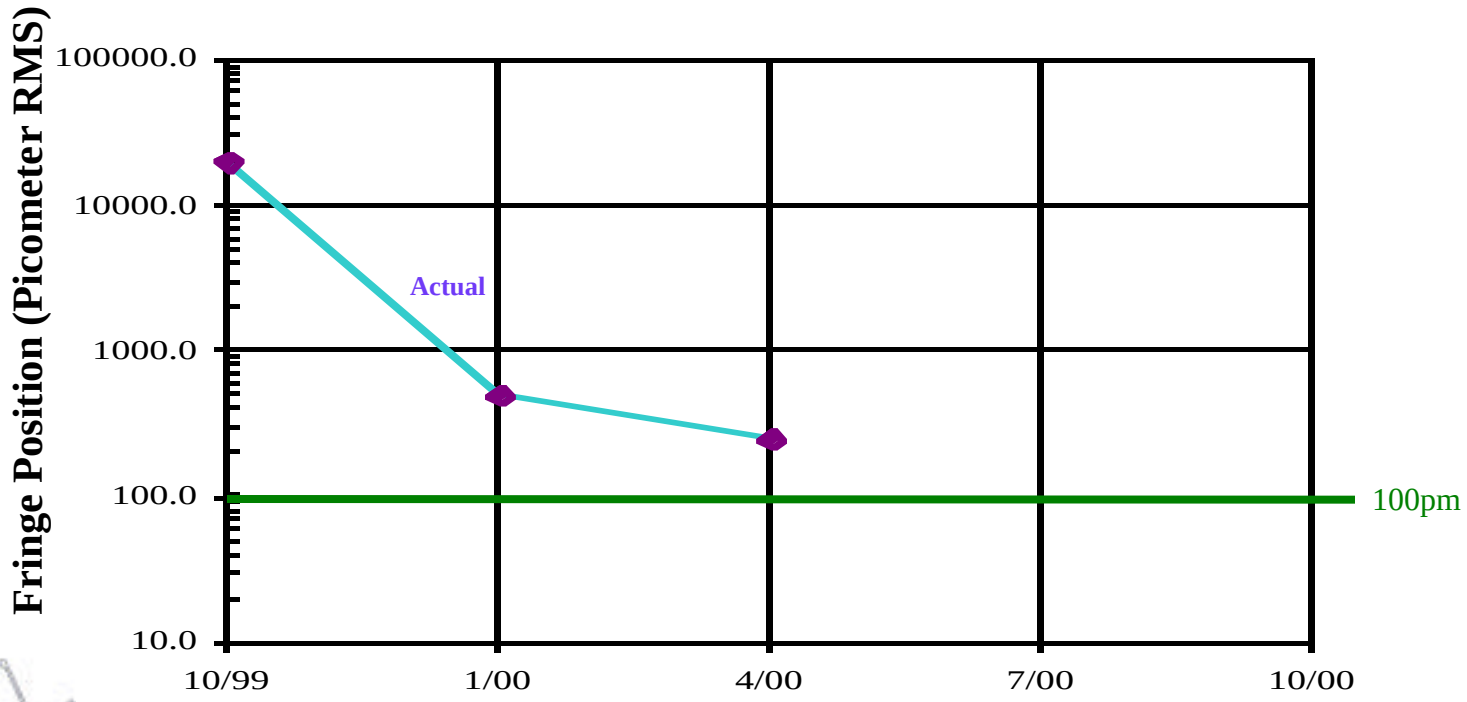
"2-Gauge" Experiment

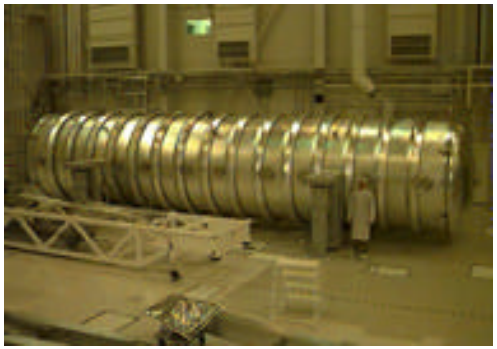
Space Interferometry Mission

A NASA Origins Mission

White Light Experiment – Progress

- "Stellar" fringe measurement accuracy – MAM interferometer test article





MAM Testbed

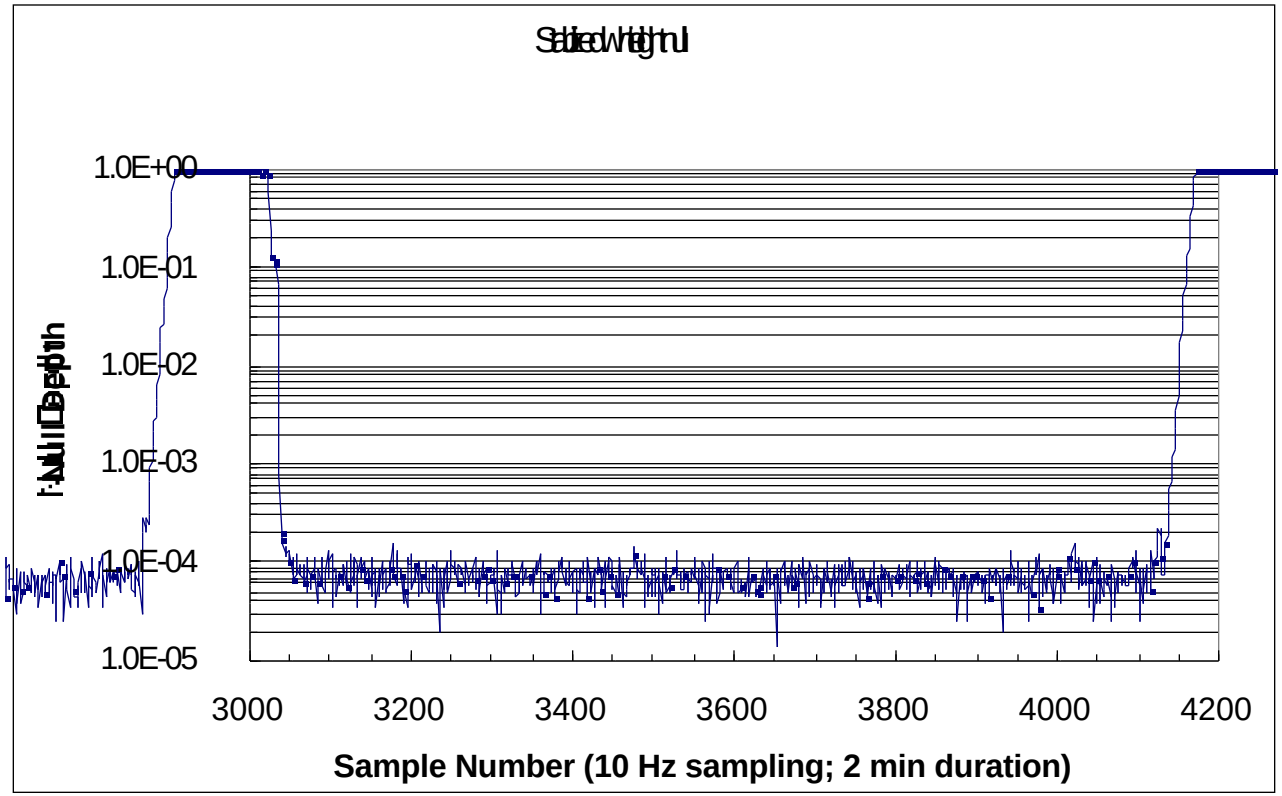
Space Interferometry Mission

SIM

A NASA Origins Mission

Stabilized White Light Null

- Two years ago this was considered the most difficult technology for SIM
- This year we have nearly achieved the requirement
  - White light null
  - Stable at less than 10^{-4}
  - 18% bandwidth
  - Single polarization

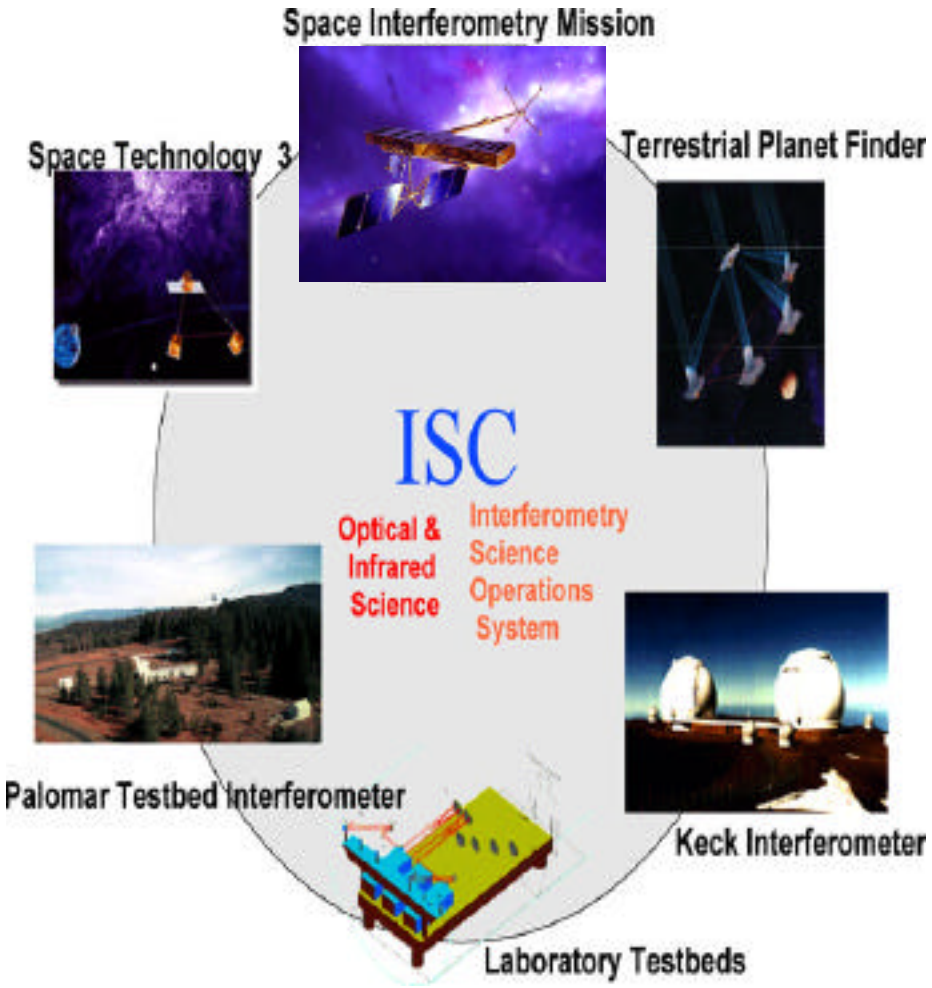


Space Interferometry Mission

A NASA Origins Mission

Interferometry Science Center

- Dr. Anneila Sargent appointed ISC Director
- JPL/Caltech collaboration
- Multi-mission capability for interferometry
- Built upon Infrared Processing and Analysis Center heritage



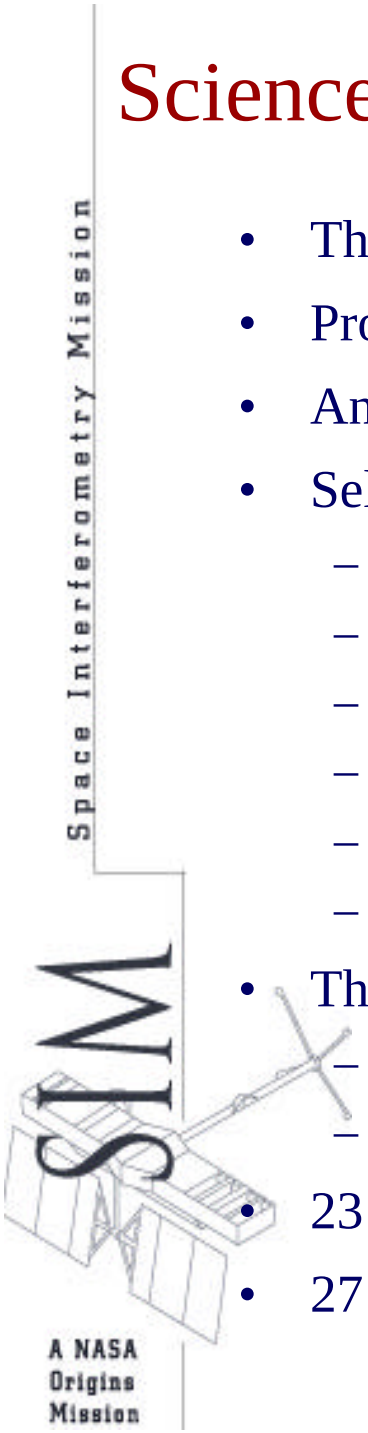
Space Interferometry Mission

SIM

A NASA Origins Mission

Science AO

- The SIM Science AO was released on February 25, 2000
- Proposals due May 26, 2000
- Announcement of selections August 2000
- Selections will be for the following:
  - As many as 8 Key Project Science Investigations
  - 1 Education and Public Outreach (E/PO) Scientist
  - Minimum of 2 Data Scientists
  - Minimum of 2 Instrument Scientists
  - Maximum of 2 Interdisciplinary Scientists
  - 1 Imaging and Nulling Scientist
- This AO will distribute about 60% of the total observing time for SIM
  - Up to 10% for each Key Project Science Investigation
  - Up to 1% for each of the Discipline Scientists
- 23 Notice of Intents were received for Key Project Science
- 27 Notice of Intents were received for individual scientists

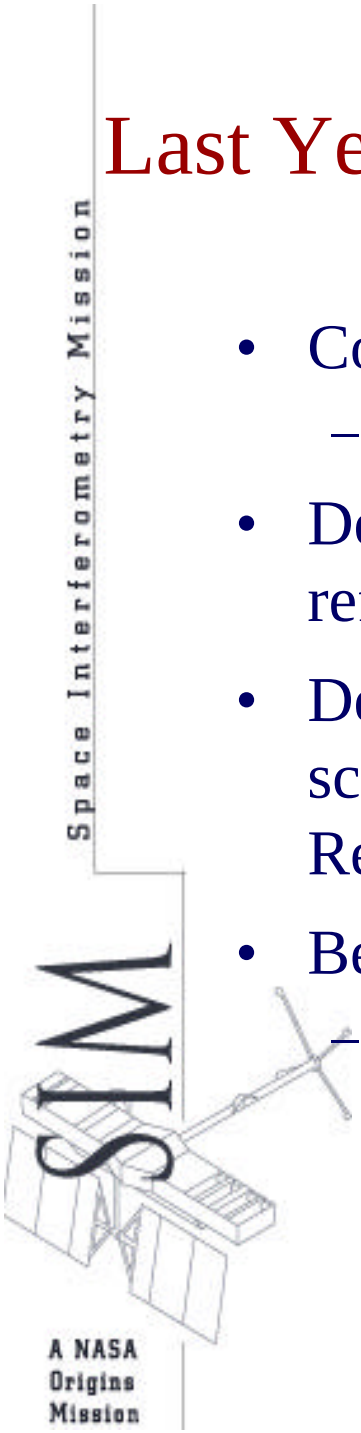


Last Year's Accomplishments – Technology

- Significant progress in nanometer technologies
  - Continued improvements on STB-1
  - Obtained STB-3 first fringes
- Nulling technology demonstrated at required level
  - Achieved 10^{-4} stable white light null
- Significant progress has been made in picometer technology, and considerable momentum established
  - Achieved 100pm precision with met gauge (Hydrogen atom diameter)
  - Demonstrated 250pm white light fringe measurement capability
- Successful at modeling nanometer performance of a full scale interferometer on a flexible structure
- Demonstrated ability to measure and predict millikelvin temperature response of optics
- Demonstrated ability to measure optical surface deformation at the 30pm level

Last Year's Accomplishments – Flight System

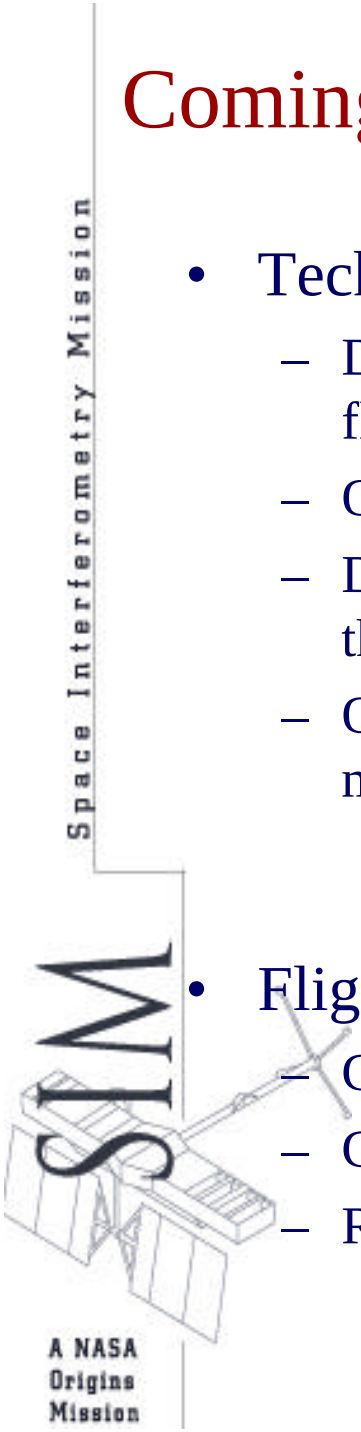
- Completed instrument design selection
  - SIM Classic is our reference design
- Developed a design description document for the reference design
- Development of level 1, 2, 3, and 4 requirements are on schedule for our September System Requirements Review (SRR)
- Began the SIM Independent Assessment
  - Held first Technical Interchange Meeting April 4 & 5



Coming Next Year

- Technology
  - Demonstrate dim star fringe tracking on STB-3 on a flexible structure
  - Obtain first fringes on MAM-1
  - Demonstrate SIM performance levels for the Met Gauge ($\leq$ 30pm) and the white light fringe ($\leq$ 100pm) measurement capability
  - Obtain initial picometer deformation measurements of optics under millikelvin temperature changes

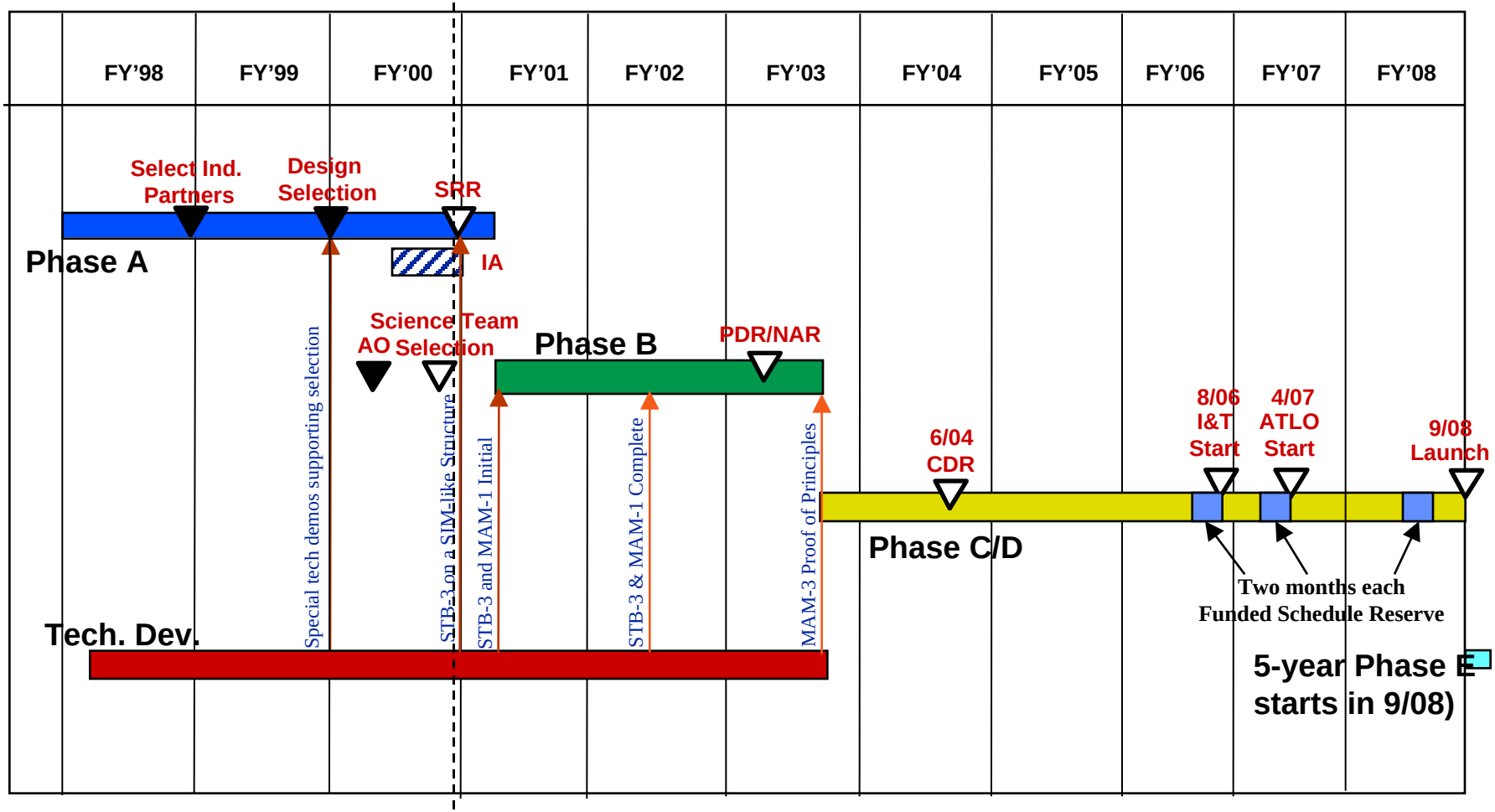
- Flight System
  - Complete the System Requirements Review (October 2000)
  - Complete the Independent Assessment (October 2000)
  - Ready to transition into Phase B (December 2000)



SIM Schedule Update

- Previous Formulation Phase schedule margin was inadequate
  - Completion of MAM-1 and STB-3 by PDR/NAR was very success oriented
  - Completion of MAM-3 proof of concept demonstration in time to influence the flight design was likely not achievable
  - Completion of critical brassboards by Implementation Phase start was success-oriented
- Previous 4 1/4 year Implementation Phase schedule inadequate
  - Delivery of metrology components on schedule was success oriented
  - Interferometer I&T and ATLO schedule was success oriented
- Current Schedule significantly reduces Project risk by extending the Formulation Phase 1 1/4 years and Implementation Phase 1 year
  - Provides adequate schedule for completion of MAM-1 and STB-3
  - Provides adequate schedule to complete MAM-3 proof of concept prior to Implementation Phase start
  - Provides adequate schedule for critical brassboard development
  - Provides the needed additional 6 months to the metrology component schedule
  - Provides the needed additional 6 months to the I&T/ATLO schedule

SIM Project Schedule



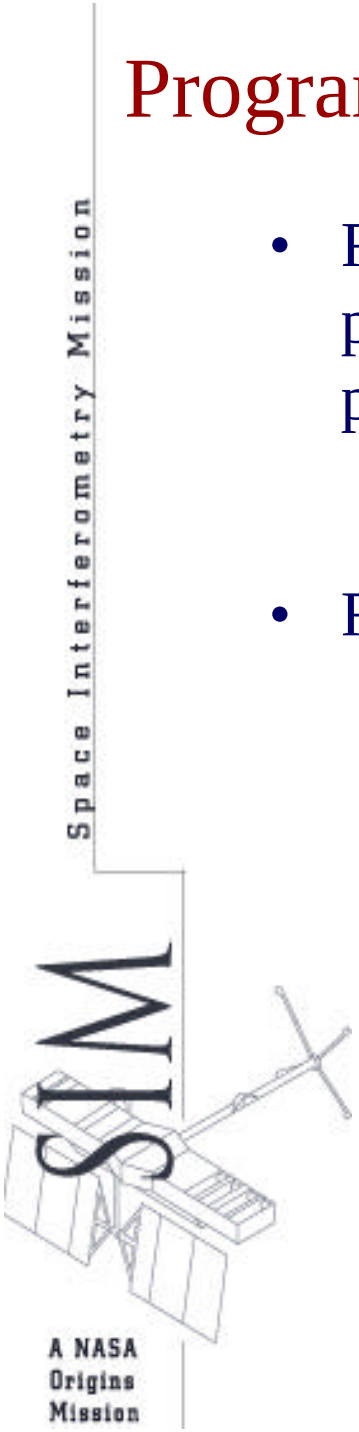
Changes since last year:

- Phase B extended 1 1/4 years
- Phase C/D extended 1 year
- Launch moves out 2 1/4 years

Program Resiliency

- Realizability of a complex mission demands program resiliency as measured by its various programmatic and technical margins

- For SIM, these include
  - Mass margin – 37%
    - EELV (Atlas V 421) selected as the Launch Vehicle
  - Power margin – 25%
  - Budget reserve – 30% (Phase C/D)
  - Schedule reserve – 6 months (Phase C/D)
  - Science – Science floor has been defined
  - Launch opportunities – Not constrained



Outreach Highlights – Michelson Fellowship Program

A program to support the scientific community in building expertise in optical and IR interferometry

Interdisciplinary team of undergraduate students designing beamcombiner for Keck Interferometer

Five integrated components

- Post-doctoral Fellows
- Graduate Student Fellowships
- Undergraduate Research
- Interferometry Summer School
- Distinguished Lecture Series

Status and Plans

- Five postdoctoral and seven graduate student fellowships awarded (among others at MIT, Harvard, U of A, SUNY, University of New Mexico, Georgia State, Caltech)
- Sponsored a Harvey Mudd Undergraduate Clinic in collaboration with Keck Interferometer
- The first summer school in Pasadena was very successful. Second will be held August 2000 at UC Berkeley

Space Interferometry Mission

SIM

A NASA Origins Mission

Takeaway Chart

- Programmatic
  - Science AO is out and the Science Team will be on board this fiscal year
  - SIM is doable for the new cost estimate
  - The current schedule significantly reduces Project risk
  - The Project will be ready for transition to Phase B this Fall
- Technology
  - Nulling technology is in hand
  - Nanometer technology is nearly in hand
  - Significant progress in picometer technology, but we still have a ways to go with picometer system level testbeds
- Flight System
  - Independent Assessment is underway
  - Development of system requirements are on track for the System Requirements Review in September 2000

Space Interferometry Mission

SIM

A NASA Origins Mission

For More Information on SIM, See Our Website at:

http://sim.jpl.nasa.gov